A PULSED FERRITE INFLECTOR FOR THE EMITTANCE MEASURING DEVICE OF THE CHALK RIVER HIGH CURRENT TEST FACILITY

J. Pachner, Jr.*

Atomic Energy of Canada Limited
Chalk River, Ontario, Canada

Summary

This paper describes a pulsed ferrite inflector for fast injection of the 750 keV, 100% duty factor proton beam of the Chalk River High Current Test Facility (HCTF), into an emittance measuring device (EMD). Tests with a low voltage prototype of a pulser have shown that a flat pulse top can be achieved by grading a lumped delay line (serving as a pulse forming network) with small additional capacitors, and that the pulse fall time can be substantially reduced by a tail biter, which at a given time diverts the current from the magnet coil and at the same time opens the primary switch of the pulser.

Introduction

The Chalk River High Current Test Facility[1] is a proton accelerator consisting of a 750 keV dc injector, beam transport system, buncher and a cw Alvarez structure to accelerate the beam to 3 MeV. The current accelerated to this energy is expected to approach 100 mA.

The HCTF is being built to investigate the problems associated with the acceleration of intense continuous proton beams. The greatest effects from space charge occur in any high current accelerator at low energies (up to a few MeV, which is the HCTF energy interval). They can cause a substantial reduction of the beam phase-space density. An emittance measuring unit is therefore a principal diagnostic device of the HCTF.

Accurate emittance measuring techniques are generally destructive, because they require placing a principal (defining) aperture plate into a beam. Since the expected power of the HCTF injector beam is 75 kW, a fast beam injection into (and removal from) the emittance measuring device (EMD) is required, in order not to destroy the principal aperture plate.

For the 750 keV energy a 5° angle has been chosen for the beam deflection from the beam stop to the EMD. A quartz plate plus a camera will be used as the detector of the EMD. This requires an approximately rectangular deflecting pulse of sufficient length to provide an adequate exposure of a film. It has been estimated that a 300 μs pulse with a droop $\leq 1\%$ and a combined rise and fall time $\leq 10\%$ of the pulse length, should satisfy the above requirement.

The specified deflection will be realised by a pulsed ferrite magnet, which is described in this paper.

The Magnet

The magnet is of a picture frame type. The ferrite frame is 206 mm long, has a gap of 50 mm and a width of 183 mm. It is made from lithium-zinc ferrite bars (of about 30 x 30 mm cross section and saturation flux density of 0.55 tesla) cemented together with Araldite 6005 epoxy resin.

The magnet is excited by a four turn copper strip winding. The magnetic field is uniform inside the ferrite frame. The fringing field is shown in Fig. 1, which is a plot of the normalised flux density B_y along the beam axis z. The magnet effective length derived from Fig. 1 is 237.5 mm. Thus the full value of the magnetic field, required in the described magnet for a 5° bend at 750 keV, is 0.046 tesla.

The Pulser

The pulser circuit is shown in Fig. 2. Its operation is de facto non repetitive. A 1Ω lumped delay line designed as an equal-capacitance mutual inductance network[2] is used as a pulse forming network (PFN). It has 20 sections with 8 μF design capacitance per section and is graded with smaller capacitors to minimise the pulse droop.

The current (i_L) through the magnet winding L is switched on by closing the switch S_1, and switched off by closing the switch S_2. The tail biter capacitor C is charged (by a separate power supply) to about the PFN voltage in the polarity shown in Fig. 2. Consequently before closing S_1, the voltage across S_2 is twice the PFN charging voltage, which requires two series coupled SCR's[3] in order to achieve the required forward blocking voltage of S_2. When S_2 is closed, S_1 is reverse biased (a series connection of a diode and an SCR provides the required reverse blocking voltage) and at the same time the voltage across the terminating resistor R_o is increased. This diverts the current from the magnet winding into the tail biter section of the circuit, and also opens S_1 by turning-off its SCR. To turn-off the SCR of S_1, the value of the tail biter capacitor C should be $\geq t_{off}/R_o$, where t_{off} is the turn-off time of the SCR. A saturating reactor S.R. protects the SCR's of S_2 by limiting the initial current during the SCR's turn-on.

The capacitors are 2 kV Condenser Products Corporation KMOC type condensers with an extended foil for high discharge currents. The SCR's are C158/159 PB type, and the silicon rectifier is A291PE type, both manufactured by General Electric. The 1Ω non-inductive terminating resistor is a group of ten standard 10Ω/1W composition resistors in parallel, and the saturating reactor core is a 3E1 ferrite torus by Ferroxcube.

Performance

The performance of a low voltage ~ 100 μs pulser prototype is reported. The magnet response time is negligible, i.e. the rise (fall) time of the deflecting force is given by the current rise (fall) time.

Using a 2Ω lumped equal-capacitance mutual inductance delay line, it was shown that a pulse droop can be practically eliminated by grading the line with small additional capacitors. This results in an impedance mismatch and consequently a longer fall time. However, since the tail biter is used to shorten the pulse fall time it does not matter. Figure 3 shows the short fall time (100-0%) of 4 μs, achieved by the tail biter as well as the required pulse flat top achieved by grading the lumped delay line. The fall time is controlled by the tail biter, it decreases as the charging voltage of the tail biter capacitor C is raised, and does not depend on the characteristic impedance of the PFN. On the other hand the rise time of the current in the magnet winding depends almost exclusively on the PFN characteristics. The rise time (10-90%) of the current generated by a 1Ω PFN (a low voltage model of the full size PFN) was measured to be 16 μs. Thus for a 300 μs pulse length the combined rise and fall time will satisfy the requirement, that it be less than 10% of the pulse length.

Acknowledgement

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References

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*NRC Postdoctorate Fellow.

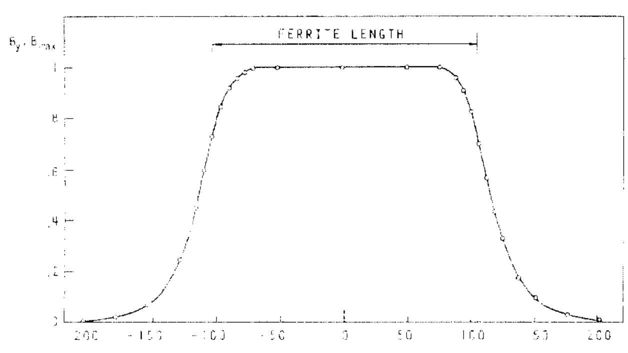

Fig. 1: Normalised flux density of the magnet along the beam axis z.

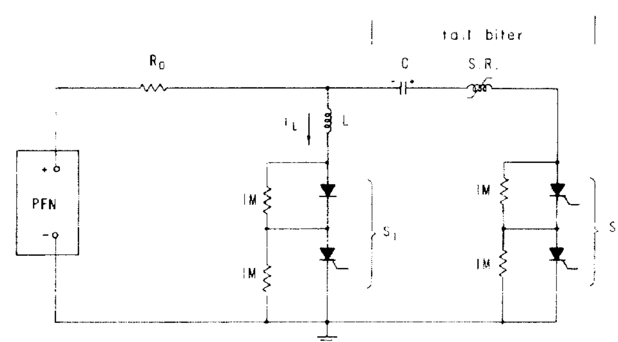

Fig. 2: The pulser circuit.

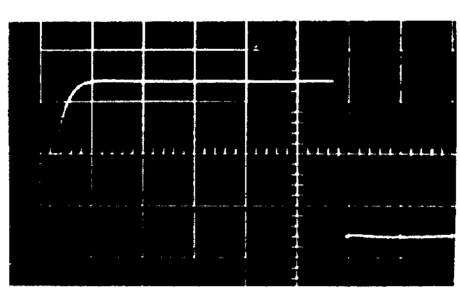

Fig. 3: The current pulse shape; horizontal line scale 20 μs/large division.